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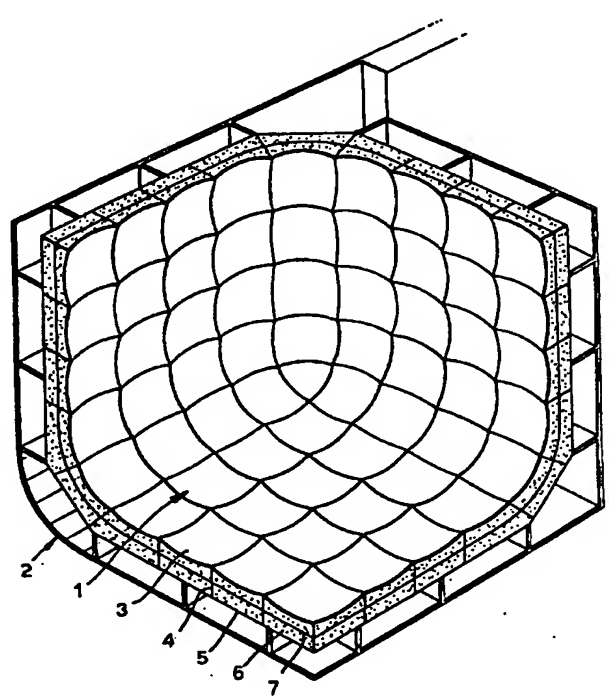
(54) Title: THERMIC INSULATED TANK AND A WALL MODULE ELEMENT FOR USE IN CONSTRUCTION OF A THERMIC INSULATED TANK

(57) Abstract

A thermally insulated tank, especially suitable for the reception of low-temperature liquids, comprising a bearing outer structure (5), an inner shell made of double-curved units (3; 9; 26, 15) dominated by membrane tension at a distance from the bearing outer structure, a plurality of support structures (4; 10; 20, 21; 37) between the units and the bearing outer structure, and thermal insulation (6; 11; 22, 25, 27) in the space between the inner shell and the bearing outer structure. The inner shell has a geometry and design which allows it to transfer, essentially as tensile stress, all forces which are due to the contents of the tank, to the points at which it is supported by support structures (4; 10; 20, 24; 37) provided in said space, which transfer all compressive forces to the bearing outer structure (5), said support structures being adapted to the units (3; 9; 26, 15) in the inner shell in such a way that thermal contraction may freely occur on geometrical change, and that the thermal insulation (6; 11; 22, 25, 27) which fills the remaining space between the inner shell and the load-bearing outer structure has no load-bearing capacity. It is of advantage if the support structures (4; 10; 20, 24; 37) are of a thermally insulating material.



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Another problem encountered, in addition to the evaporation loss, is that the metal structure components in and around the tank have a tendency to become brittle and lose strength due to the effect of low temperatures. At temperatures such as that of liquid methane at atmospheric pressure or liquid propane at atmospheric pressure, common ferrous materials, such as low carbon steel, will lose a great degree of their energy-absorbing capacity when exposed to large stress loads, i.e., loss of impact resistance. Storage tanks in general, and in particular those on board ships, may well be subjected to shock or impact loads. When materials having a low boiling point such as methane or natural gas high in methane content, or propane are liquefied for storage and transport, one must thus be particularly aware of the danger of loss of impact resistance in steel walls and the like.

Physical failure in a wall of a tank containing cold liquid hydrocarbon, for example, liquid methane, may result in great danger to both life and property. In order to reduce the danger of a failure of this kind, it is known to store gases such as liquid methane or propane or other cold materials in steel tanks or containers equipped with internal thermal insulation of considerable thickness. By placing the insulation on the inside of the tank wall instead of on the outside, the tank wall material will be capable of being kept at an essentially normal ambient temperature through the thickness of the tank wall, even if the tank is fully loaded with cold liquid. The solution makes possible the use of low carbon steel, i.e., relatively cheap steel in a tank structure, such that one does not have to make use of expensive steel alloys or other materials which maintain significant impact resistance at low temperatures.

It will normally be undesirable to allow direct exposure of the thermally insulating material to the cold liquid which is stored or transported. In order to avoid such direct exposure, it has therefore been proposed to place a lining or

THERMIC INSULATED TANK AND A WALL MODUL ELEMENT FOR USE IN CONSTRUCTION OF A THERMIC INSULATED TANK.

The invention relates to a thermally insulated tank, especially suitable for the reception of low-temperature liquids, comprising a bearing outer structure, an inner shell formed of double-curved units dominated by membrane tension at a distance from the bearing outer structure, a plurality of support structures between the units and the bearing outer structure and thermal insulation in the space between the inner shell and the outer structure.

The invention also relates to a modular wall unit for use in the construction of a thermally insulated tank, especially suitable for the reception of low-temperature liquids. The invention has been especially developed in connection with the desire and the need for the transport of liquefied gases, such as LNG and LPG. Several hydrocarbons have a boiling point and critical temperature that are so low and a critical pressure which is so high that is not practical and/or theoretically possible to keep them liquid at normal temperatures solely by the application of pressure.

For many years a great deal of work has been done to try to solve the problems within the field of storage and transport of hydrocarbons in liquid state and at essentially atmospheric pressure. Under such conditions the cold liquids are placed in thermally insulated tanks and are allowed to evaporate or boil off as heat leaks in through the tank wall. The resulting vapours may be conducted directly into the atmosphere, used as gas fuel or recondensed by means of suitable refrigerating equipment and returned as liquid to the insulated tank. Clearly, the efficiency and economy of this kind of storage and transport of low-temperature liquids will to a great extent be dependent upon the thermal insulation used for the tank.

inner tank shell, usually of metal, inside the insulation. A lining of this kind could, for example, be of aluminium or another metal such as stainless steel, which maintains a considerable impact resistance even at very low temperatures. However, a lining of this kind may in itself present problems in a conventional tank structure. Even if the lining can be adapted adequately to the insulation - usually insulation blocks - at room temperature, it will have a tendency to withdraw from the insulation, at least in certain boundary layers when the tank structure is cooled during filling, as during this process various thermal contractions may occur. Such withdrawal will give rise to unwanted voids in the tank structure.

As mentioned, in recent years there has been great interest in the transport of liquefied gas on board suitable tank ships. Safe and efficient storage and transport of liquid natural gas (LNG), for example, liquid methane, presents several problems when it is a question of transport on board a ship. Such problems have many causes, in particular static and dynamic movements, bending and deformation in the structure of the ship as a result of loads and wind and wave forces, and as a result of stress which is due to extreme temperature variations in the tank during loading and unloading, which extreme variations, as previously mentioned, will be capable of giving rise to severe thermal expansions and contractions in the tank structure. Such stress will be transferred between the hull of the ship and the tank via the tank's support system.

Because of these serious problems, the authorities and classification companies have provided rules for the marine transport of liquefied gas. As a result hereof, many different support systems for tanks aboard ships which are intended for this type of cargo have been suggested. The use of a double-walled tank has been proposed, where the tank system is resiliently mounted in the hull, thereby minimising

the transfer of stress from the hull structure to the tank and enabling the absorption of small relative movements between the hull and the tank. Such arrangements are extremely expensive since they require double tank systems and the support structure will be relatively complicated. The actual construction of the tank is made more complex by the fact that the outer tank must be built around the inner tank and that once the tank walls have been completed, some welded joints in the structure can no longer be inspected and tested.

A known type of tank for the transport of liquefied gas on board a ship is the so-called integrated tank or membrane tank. A cargo tank of this kind is constructed of a light or thin material which is not designed to take a great load in its own plane. The load pressure is transferred at right angles (perpendicular to the membrane) onto the hull structure of the ship. Such tank structures are double-walled (primary barrier and secondary barrier) cargo systems.

One of the objectives of the present invention is to provide a thermally insulated tank, especially suitable for the reception of low-temperature liquids, where the actual tank wall will be capable of taking lateral load from the liquid and of transferring this load to a support structure, which then in turn transfers the load to an outer strength-bearing structure.

Another objective of the invention is to provide a thermally insulated tank constructed such that small contraction forces arise when temperatures change.

Yet another objective of the invention is to provide a thermally insulated tank constructed such that membrane tension will in essence occur in the tank wall, i.e., mimimum bending stress.

Another of the objectives of the invention is to make possible

the provision of an air layer between the tank wall and the insulation and channels in the insulation with a view to detecting and locating a leakage in the tank wall.
One particular objective of the invention is to make possible the use of cost effective panels or tank units for the construction of a thermally insulated tank.

Another of the objectives of the invention is to make a thermally insulated tank such that it can easily be secured to the outer bearing structure of a ship so that the floating up of the tank should liquid enter the ship is obviated.

According to the invention a thermally insulated tank is therefore proposed, especially suitable for the reception of low-temperature liquids, comprising an outer bearing structure and an inner shell made of membranes at a distance from the outer bearing structure. The inner shell has a geometry and design which enables it to transfer, mainly in the form of tensile stress, all forces which are due to the contents of the tank, to the points at which it is supported by the support structure provided in the said space, which transfer all compressive forces to the outer bearing structure, said support structures being adapted to the units in the inner shell such that thermal contraction may occur freely on geometrical change, and that the thermal insulation filling the remaining space between the inner shell and the load-bearing outer structure has no load-bearing capacity.

In a tank of this kind, the tank wall enclosing the liquid will be capable of taking lateral load from the liquid and of transferring this load to the bearing outer structure, the forces being transferred through the membrane-confining support structures. The tank will consist of a plurality of membranes where the membrane forces will be relatively small. The insulation will not transfer any forces worth mentioning from the inner shell to the bearing outer structure.

It is of particular advantage if the thermal insulation material can comprise a plurality of blocks of thermally insulating material lying in the plane of the wall, each of which being connected to one of the said support structures. It is especially advantageous if the said blocks can be placed very close to one another.

Each individual block of thermally insulating material may very advantageously be a component of a tank wall unit which, in the tank wall from within and out, comprises a membrane and a support structure connected thereto. This gives an especially advantageous possibility of constructing the tank by means of units of varying sizes.

Several continuous barriers may be incorporated into the tank wall and, in a preferred embodiment, the bearing support structure may in this connection be divided in the plane of the wall by the intermediate flat structure, which will then represent a secondary barrier.

According to the invention, the bearing support structure may enclose the insulation material in a tank wall unit, or it may penetrate the insulation material in a tank wall unit.

In the inner shell, the said respective membranes may be reciprocally spaced apart in the plane of the wall, in that wall surface filling membranes are inserted therebetween.

An inserted, filling membrane of this kind may to advantage have a folded edge between two adjacent support structures in an outward direction of the tank, thereby providing channels.

Between the bearing outer structure and the support structures there are advantageously provided attachment means for retaining and securing against floating.

A thermally insulated tank according to the invention is

especially well-suited for use on board a ship where, when this is the case, the bearing outer structure may well be a part of the hull of the ship.
The invention also relates, as mentioned, to a modular wall unit for use in the construction of a thermally insulated tank, especially suitable for the reception of low-temperature liquids, and such a modular wall unit according to the invention is to advantage characterised in that it comprises a hollow support structure having a first and second end and a closed periphery, a membrane borne by the support structure at the first end, and a block of thermally insulating material, borne by the support structure, between said first and second end.

The support structure may, in an advantageous embodiment, enclose the block like a frame. In a second advantageous embodiment, the support structure may extend through the block.

According to the invention, the support structure may be divided parallel to the membrane and between the membrane and the block, a flat structure lying between the parts of the support structure which in form is similar to the block. This flat structure will be capable of being used as a secondary barrier.

It is particularly advantageous if the block has an approximately right-angled rectangular form, as this facilitates the assembly of the blocks in the tank wall.

It is of particular advantage if the frames have side edges bowed or curved in the wall plane. Normal or strictly right-angled rectangular frames will, when assembled, form a right-angled pattern. Upon cooling the pattern structure will shrink, and there is the risk of cracking. If the sides in the frames are curved and the corners secured, the sides will straighten out upon cooling.

It is of advantage if means for securing the modular wall unit to a strength bearing structure, for example, a part of the hull are provided at said second end of the support structure.

Advantageously, the support structure is essentially filled with thermally insulating material between the membrane and the flat structure.

The invention shall now be explained in more detail with reference to the drawings where:

Fig. 1	shows a section of the hull of a ship with a cut-through membrane tank according to the invention;
Fig. 2	shows modular wall units assembled in the wall plane;
Fig. 3	is a section through the assembled modular wall units in Figs. 1 and 2;
Fig. 4	shows a right-angled structure pattern, in contrast to
Fig. 5	which illustrates a structure pattern with curved frame sides;
Fig. 6	is a section of a tank wall, having a modified membrane wall embodiment;
Fig. 7	illustrates the special membrane wall in Fig. 6 in a construction phase;
Figs. 8-16	illustrate different steps during the manufacture of a modular wall unit as shown in Fig. 17 and which forms a part of the wall shown in Figs. 6 and 7;
Fig. 17	illustrates a modular wall unit;
Fig. 18	illustrates a filling thermally insulating member for use in the wall in Figs. 6 and 7;
Fig. 19	shows a piece of membrane for use as a filling member in the wall embodiment in Figs. 6 and 7;
Fig. 20	is a purely schematic illustration of how channels may be provided in the tank wall and

used for the detection of leakages;

Fig. 21 is a section of the hull of a ship having a cut-through membrane tank according to the invention;

Fig. 22 is an enlarged section of the tank wall including a unit according to the invention;

Fig. 23 shows a partially cut through unit which is used in the embodiment in Fig. 21; and

Fig. 24 is a perspective outline of an attachment means.

Fig. 1 illustrates a section of a membrane tank 1 in the hull 2 of a ship. The membrane tank is built up of a plurality of membranes 3 which are confined by and supported by respective support structures 4 against a bearing outer structure 5, which is a part of the hull 2. The membrane-confining support structures 4 are of a thermally insulating material. Between the inner shell in the tank, which is formed by the membranes 3, thermally insulating material 6 is provided. A secondary barrier is indicated by means of reference numeral 7.

The tank embodiment schematically illustrated in Fig. 1 may, for example, be built up by means of wall unit modules 8 of the type illustrated in Figs. 2 and 3.

Each of these modules has an approximately right-angled rectangular form and comprises, from within and out, a correspondingly rectangular membrane 9, a support structure 10 rectangular in form, and a block 11 of a thermally insulating material.

Each individual frame is to advantage made with bowed or curved sides, as is indicated in Fig. 1. The purpose thereof will be seen from a study of Figs. 4 and 5. In Fig. 4, normal rectangular frames are conceived assembled and a structure pattern with straight lines in a right-angled pattern emerges. Upon cooling the structure will shrink, and there is a risk

of cracking. By bending the frame sides and securing the corners, as outlined in Fig. 5, sides which straighten out upon cooling are obtained.

The tank wall illustrated in section in Fig. 3 is built up of two layers of modular wall units, with an intermediate flat structure 12, which forms a secondary barrier (the membrane 9 = primary barrier). One can also see two frames 10 placed upon one another in Fig. 3 as a support structure divided by means of the flat structure 12. The insulation in the support structure outside the secondary barrier 12, may optionally extend right up to the flat structure or secondary barrier. Usually, less stringent requirements are made for the secondary barrier than the primary barrier, because the membrane forces will be totally different in the two flat structures. In a practical embodiment, for example, the flat structure/secondary barrier will be made of a 1 mm thick GRP membrane, whereas the primary barrier or membrane 9 will be made in the form of a 10 mm thick GRP membrane (GRP - Glassfibre-Reinforced Plastic).

In the module embodiment shown and described, the tank is thus constructed of modular units, the unit size of which is, for example, length x breadth x height = 1 m x 1 m x 0.25 m. The modular units are joined together structurally in that the membranes 9 and the flat structures 12 are joined and insulation is pressed together (and possibly bonded) at the end surfaces, such that the insulation is also made continuous.

Fig. 6 shows a section of an inner tank wall or an inner shell formed by membranes in a different embodiment than the one shown in Figs. 2 and 3. Fig. 7 shows a tank wall of this kind during construction, before the filling membrane pieces 15 are inserted between the, in this case circular, membranes 26, confined by support structures. This type of tank wall is built up of modular units 17 which are assembled in the wall

plane. These modular wall units are constructed in a special way, which shall now be described in more detail with reference to Figs. 8 - 17.

Each individual modular wall unit 17, see Fig. 17, is manufactured in the following way: A casting box 18 (Fig. 8) is provided having a bottom wherein a circular slot 19 has been removed. The box may have a length and breadth of 1 metre, and the slot may be 3 cm in depth. In the slot 19, there is placed a tubular member 20 (Fig. 9), which will form a hollow support structure in the modular wall unit. In Fig. 10, the casting box and tubular support are shown cast, i.e., a foaming of thermally insulating foam material has been carried out in the box 18 (also inside the tubular support 20). Attachment members 21 are mounted on the tubular support 20. The purpose of these will be described in more detail below.

In the said practical exemplary embodiment of length x breadth = 1 m x 1 m for the box 18, it may be expedient for the box to have a height of 15 cm, and the tubular support 20 may, in the cast position in Fig. 10, project 7 cm above the box.

The thus cast unit is removed from the mould (the box) and turned, as shown in Fig. 11. The unit now exists in the form of a cast block 22 of thermally insulating material, penetrated by the tubular support 20.

In Fig. 12 the unit illustrated is the same as that shown in Fig. 11. A flat structure 23 (in Fig. 13) is placed on the unit. This flat structure will form a subsequent secondary barrier in the tank and is bonded to the tubular support 20. Between the block 22 and the flat structure 23, there is a space of 3 cm in the given dimensional example.

An additional tubular member 24 with insulation 25 cast therein (Fig. 14) is provided with a membrane 26 (Fig. 15),

which is bonded to the tubular member 24. This additional tubular member 24 with appurtenant membrane 26 is placed upon and bonded to the unit shown in Fig. 13, as is illustrated in Fig. 16.

The thus produced modular wall unit 17 is shown in a greater scale in Fig. 17. These units are assembled as shown in Fig. 7, for the formation of panels of varying sizes, respectively for the formation/construction of a thermally insulated tank having an inner shell as shown in Fig. 6. The membranes 26 discussed in connection with Figs. 8 - 16 correspond to the membranes 26 in Fig. 6.

As mentioned, the modular wall units 17 are assembled as illustrated in Fig. 7, the insulation blocks 22 being assembled and bonded. The flat structures 23 are also bonded together so that a continuous flat structure is formed, which will function as a secondary barrier in the tank. Filling insulation blocks 27 are placed (see also Fig. 18) between the tubular connecting pieces 24, upwardly directed in Fig. 7 and inwardly directed in the tank. These blocks are also bonded in place.

Filling membrane pieces 15 (Fig. 6) are placed between the membranes 26, and are joined to the membranes 26, whereby a continuous inner shell in the tank is formed. A filling membrane piece 15 of this kind is shown in perspective view in Fig. 19. As shown in Fig. 19, a membrane piece of this kind 15 has two folded edges 16 running opposite to and parallel to one another. The height of the edge in the dimensional example is equal to the height of the part of the tubular support 24 which projects up from or out relative to the insulation blocks 27. These folded edges 16 will extend between adjacent tubular supports 24, as is shown in Fig. 20, where only the folded edges 16 of the membrane pieces 15 and not the membrane pieces themselves are shown. It can be seen that the folded edges 16 will form channels 16, as indicated

by means of arrows and the broken line, between the insulation and the inner membrane shell in the tank. Channels are thus formed through which, for example, nitrogen may be flushed, thereby detecting in a known way per se any leakage. If in the dimensional example the tubular connecting piece 24 has an axial dimension of 20 cm and the filling insulation block 27 in Fig. 18 has a thickness of 15 cm, the channels that are formed will have a height of 5 cm, which is then also the height dimension of the folded edge 16.

The membrane tank 31 in the hull 32 of a ship, shown in section in Fig. 21, is built up of units 33 secured to the inner skin 34 of the ship. The units are of the type that are shown in Fig. 23.

The unit 33 is built up around a central cylindrical structure 37. This cylinder is made of an insulating material which at the same time has the necessary mechanical strength to transfer the loads from the membranes 39 and 40 to the inner skin 34. Outermost against the inner skin 34, there is a layer of insulation 38 made of a suitable material, for example, polyurethane foam. The insulation block 38 is attached to the cylinder 37 with an adhesive or in another way. On the liquid side of the insulation 38, there is a liquid-impermeable secondary barrier 41 of a suitable material, for example, glassfibre reinforced polyester. This barrier is continuous through the cylinder 37, which thus must be produced in two halves which are joined together by means of bonding/casting above the secondary barrier 41.

The secondary barriers in the different units are cast together after the units have been mounted onto the inner skin.

For the purpose of providing an overlying fold, the secondary barrier in each individual unit is larger than the outer measurements of the unit. On the liquid side of the secondary

barrier there is a second layer of insulation 42. It is composed of two blocks for each unit. One [block] 43 is inside the cylinder and is attached thereto. This is lower in height than the cylinder, and permits the necessary curve of the primary liquid barrier 40. The space 45 between the insulation 43 and the primary barrier 40 is in connection with corresponding space 46 outside the cylinder in that there are small holes 44 in the cylinder.

The second insulation block 47 fills the space between the cylinders after the units have been assembled. It is thus not a part of the prefabricated unit. The height of the block 47 is less than that of the cylinder 37, so that it permits the necessary curve of the primary barrier 39 and thus also a space 46 between the insulation and the primary barrier.

All spaces 45 and 46 communicate with one another via the holes 44. This can be used to monitor leakages through the primary barrier in that a gas can be flushed on the inside of the barrier. Detection of liquid from the tank, and optionally an added tracer, in this gas is tantamount to a leakage in the primary barrier.

The primary liquid barrier consists of two parts, both double-curved. One part 40 is attached to the cylinder 37 and forms a part of the prefabricated unit. The other part 39 has a geometry which means that it, together with part 40, constitutes a continuous structure.

The installation and assembly of the units take place in that a prefabricated unit, consisting of a cylinder 37, four mounts 35, a second insulation layer 38, a secondary barrier 41, a central part of the first insulation layer 43 and a primary barrier 40, is attached to the inner skin (cf. Fig. 22). The insulation layers 38 in the individual units can be joined together by means of bonding or similar. The secondary barriers 41 are cast together in the overlapping fold. The

filling block of the first insulation layer 47 is installed between the units, attached optionally to the neighbouring blocks and the adjacent cylinders. Finally, the filler part 39, which is prefabricated by the primary barrier, is attached to the previously installed part 40 by an overlapping casting.

In the parts of the tank where different parts of the inner skin meet at an angle, the units are adapted by means of a bevelling of the insulation at the ends 48. In other respects, the installation is carried out in the same way. The primary barrier 39 between the cylinders will have to be adjusted individually, for example, by casting on site.

The tank 31 is as mentioned built up of units 33 attached to the inner skin 34 of the ship. The size of the unit will be determined by practical considerations, for example, that it must be capable of being carried by one person. A typical size will be 1 m x 1 m x 0.4 m. The attachment mechanism consists of a member 50 attached to the inner skin 34. Each member is equipped with a mount which is adapted to the mount and attachment mechanism of the attached units. The mount is found in a male (35a) and female (35b) form. Each member has two male and two female mounts. The female and optionally male mounts are of a length that allows them to extend beyond the edge of the unit 36 and are accessible when the unit is mounted. The attachment mechanism will lock the units to one another and to the inner skin (cf. Figs. 22 and 24).

It will be evident that the liquid barrier is composed of double-curved surfaces, a significant portion of which is constituted by spherical calottes. A surface of this kind is well suited for attenuating the wave energy which occurs in a tank in motion, e.g., a tank aboard a ship. The projecting parts of the barrier will brake any liquid movement parallel to the wall and gas pockets which are caught in the hollow spaces will also attenuate pressure thrust which occurs when a wave hits a wall perpendicularly.

Structurally, the tank consists of a wall which takes lateral forces without the occurrence of any significant bending stress. This is achieved in that the wall is concavely double-curved, as close to a spherical calotte as possible where it is not mounted. A geometry of this kind gives a pure tension pattern and is advantageous with a view to the development of cracks. The wall is mounted at many points and has a geometry which means that these points are not rigidly connected to one another via the wall. This means that less stringent requirements can be made with regard to the supporting structure being plane, and that there occur negligible tensions in the wall if the supporting structure bends. Both these facts mean that the invention is highly suited for installation on board a ship.

By virtue of the fact that the wall is this mounted at different points in a bearing structure, a situation is achieved wherein the underlying insulation is not loaded with lateral forces from the contents of the tank. The geometry with which the tank wall has been endowed, viz. curved, also means that contractions in the tank wall are taken as local changes in radius. This will cause small local tension, but global tensile stress is avoided.

A tank wall construction is made possible by means of the invention where the tank wall is capable of taking lateral load. The inner shell is formed such that in essence membrane tension occurs, and it is supported by a structure which is made of a material of the necessary strength and sufficient thermal insulation properties. Necessary insulation in the tank wall is attached to this bearing structure or support structure (the insulation does not take any load).

The invention makes it possible to produce tanks having the properties that are desirable with regard to geometry, form, strength, insulation, secondary barrier, leakage detection, etc, and a number of problems are obviated/reduced by virtue

of the fact that the tank can be built without any sharp corners, i.e., it will be less subject to so-called sloshing. The support or bearing structure is not continuous, but in the form of a finely meshed network of support structures, and the tank wall is formed of curved surfaces, i.e., surfaces which are less vulnerable to contraction forces at low temperatures.

By employing modular wall units which are used in the surfaces (bottom, wall and ceiling), one can expediently make units designed for corners and transitions between bottom - wall, wall - ceiling, etc. These corners and transitions are also made in such a way that the tank wall absorbs the load just as standard modular units do. In this way, the thermally insulated tank can be built so as to be adapted to a "random" outer structure.

The attachment members are used to secure the units to the outer structure so as to prevent floating should liquid come in between the modular units and the outer structure.

Although in the exemplary embodiments it is assumed that there are two barriers, the invention can be carried out with only one barrier.

The invention is not limited to the storage and transport of low-temperature liquids. For instance, it could also be used in the case of chemically reactive liquids.

The invention differs from existing structural solutions on several major points.

Firstly, it is well-suited for production by using prefabricated units. These can be produced so as to be almost complete in a separate production plant. The installation work in the actual tank is thus reduced to a minimum. This results in low total costs. If special conditions so require, the tank may alternatively be constructed as a continuous

structure at the site of installation.

Secondly, the liquid-impermeable barrier or barriers is/are formed so as to be well-suited for construction in a laminated, non-metallic material. This results in simplified production and installation methods and generally reduced costs. If special conditions, e.g., the chemical properties of the liquid, so require, the barrier or barriers may, however, be made of metallic materials.

Since the invention is based on or built up around a single unit it is simple to adapt random geometries and total dimensions, which is an advantage.

In contrast to conventional membrane tank design, where the joint between the individual parts/extents of the liquid barrier consist of welded joints, the joints in this invention (in its non-metallic embodiment) are made in the form of overlapping casting. The barrier is thus completely continuous.

Patent claims

1.

A thermally insulated tank, especially suitable for the reception of low-temperature liquids, comprising a bearing outer structure (5), an inner shell made of double-curved units (3;9;26,15) dominated by membrane tension at a distance from the bearing outer structure, a plurality of support structures (4;10;20,21;37) between the units and the bearing outer structure, and thermal insulation (6;11;22,25,27) in the space between the inner shell and the bearing outer structure, characterised in that

the inner shell has a geometry and design which allows it to transfer, essentially as tensile stress, all forces which are due to the contents of the tank, to the points at which it is supported by support structures (4;10;20,24;37) provided in said space, which transfer all compressive forces to the bearing outer structure (5), said support structures being adapted to the units (3;9;26,15) in the inner shell in such a way that thermal contraction may freely occur on geometrical change, and that the thermal insulation (6;11;22,25,27) which fills the remaining space between the inner shell and the load-bearing outer structure has no load-bearing capacity.

2.

A thermally insulated tank as claimed in Claim 1, characterised in that the support structures (4;10;20,24;37) are of a thermally insulating material.

3.

A thermally insulated tank as claimed in Claim 1 or 2, characterised in that the thermal insulation in the space between the inner shell and the outer structure comprises a plurality of blocks (11;22;38) of thermally insulating material lying in the wall plane, each of which is connected to one of the said support structures (10;20;37).

4.

A thermally insulated tank as claimed in Claim 3, characterised in that the said blocks (22;38) are assembled very close to one another.

5.

A thermally insulated tank as claimed in Claim 3 or 4, characterised in that each individual block (11;22;38) of thermally insulating material is a component of a tank wall unit which in the tank wall, from within and out, comprises a membrane (9;26;40) and a support structure (10;20;37) connected thereto.

6.

A thermally insulated tank as claimed in one of the preceding claims, characterised in that the bearing support structure (10;20,24,37) is divided in the wall plane by an intermediate flat structure (12;23;41).

7.

A thermally insulated tank as claimed in Claim 5 or 6, characterised in that the bearing support structure (10) encloses the insulation material (11) in a tank wall unit.

8.

A thermally insulated tank as claimed in Claim 5 or 6, characterised in that the bearing support structure (20;37) penetrates the insulation material in a tank wall unit.

9.

A thermally insulated tank as claimed in one of the preceding claims, characterised in that the said respective membranes (26;40) are reciprocally spaced apart in the wall plane, in that wall surface filling membranes (15;39) are inserted therebetween.

10.

A thermally insulated tank as claimed in Claim 9, characterised in that an inserted, wall filling membrane (15) has a folded edge (16) in an outward direction in the tank between two adjacent support structures (24).

11.

A thermally insulated tank as claimed in one of the preceding claims, characterised by attachment means (21;50,35) provided between the bearing outer structure (5) and the support structures (4;10;20).

12.

A thermally insulated tank as claimed in one of the preceding claims, characterised in that the bearing outer structure (5;34) is a part of the hull (2;32) of a ship.

13.

A modular wall unit for use in the construction of a thermally insulated tank, especially suitable for the reception of low-temperature liquids, characterised in that it comprises a hollow support structure (10;20,24;37) having a first and second end and a closed periphery,
a membrane (9;26;40) borne by the support structure at the first end, and
a block (11;22;38) of thermally insulating material, borne by the support structure, between the said first and second ends.

14.

A modular wall unit as claimed in Claim 13, characterised in that the support structure (10) encloses the block (11) like a frame, preferably a frame having curved sides.

15.

A modular wall unit as claimed in Claim 13, characterised in that the support structure (20;37) extends through the block (22;38).

16.

A modular wall unit as claimed in Claim 15, characterised in that the support structure is divided parallel to the membrane (26), between the membrane (26;40) and the block (22;38), and in that between the parts of the support structure (20,24) there is a flat structure (23;41).

17.

A modular wall unit as claimed in one of Claims 13-16, characterised in that the block (22) has a right-angled rectangular form.

18.

A modular wall unit as claimed in one of the preceding Claims 13-17, characterised by means (21;50,35) provided at the second end of the support structure (4;10;20;37) for securing the modular wall unit to a strength-bearing structure (5;34).

19.

A modular wall unit as claimed in one of the preceding Claims 16-18, characterised in that the support structure (24;37) is partially filled with thermally insulating material (25;47) between the membrane (26;40) and the flat structure (23;41).

Fig.1.

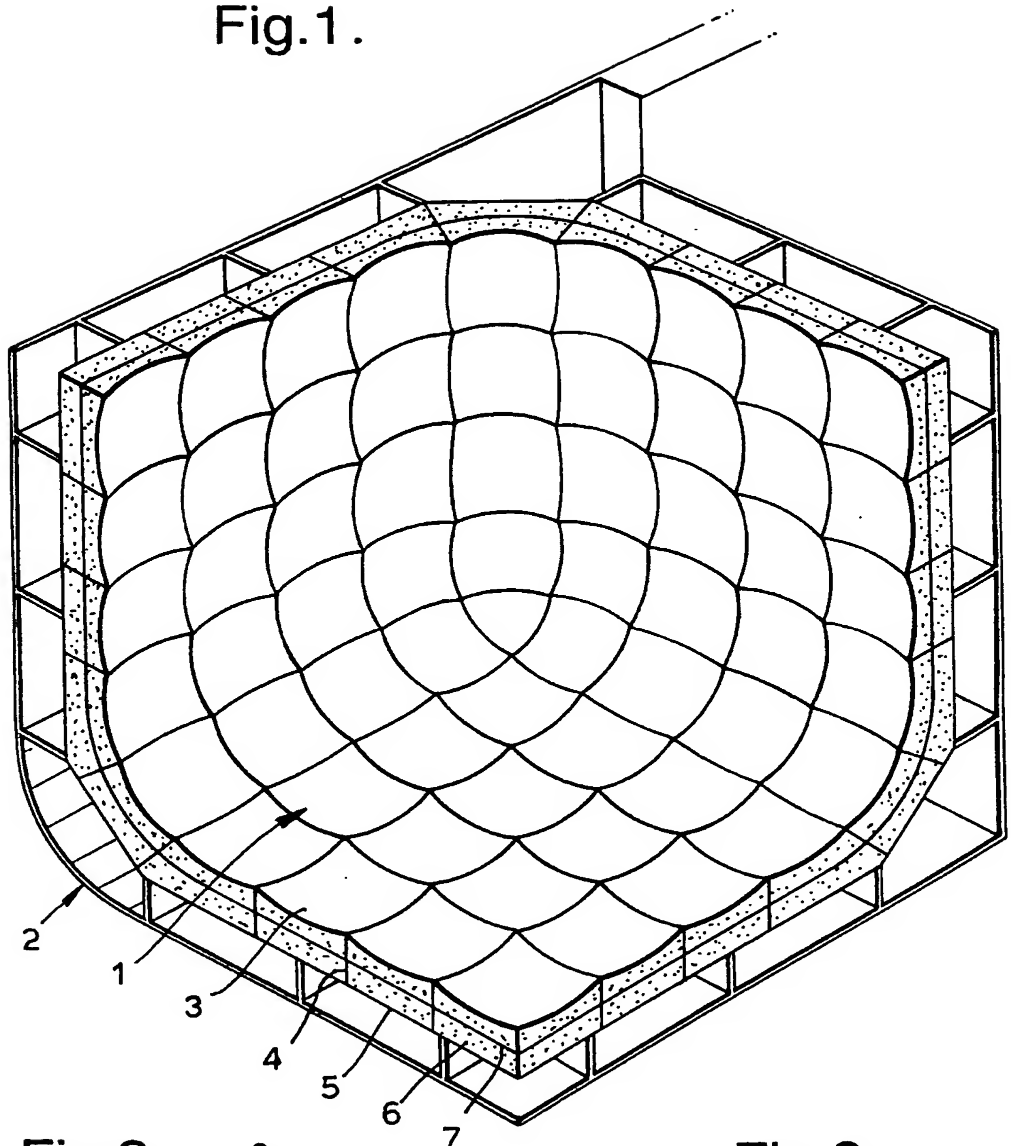


Fig.2.

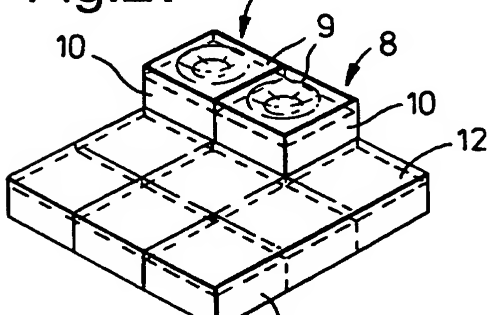
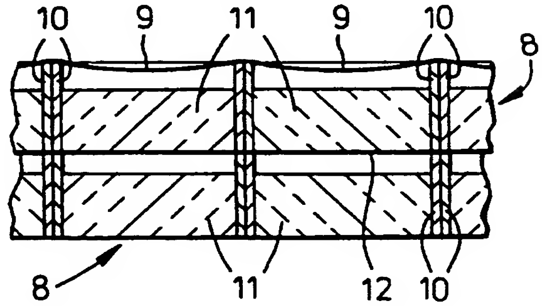


Fig.3.



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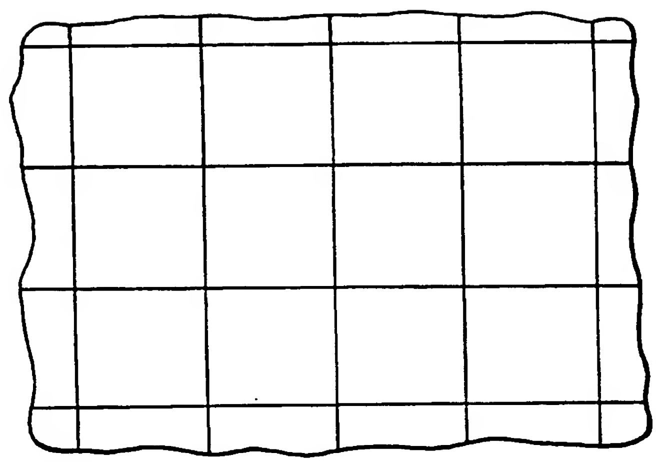

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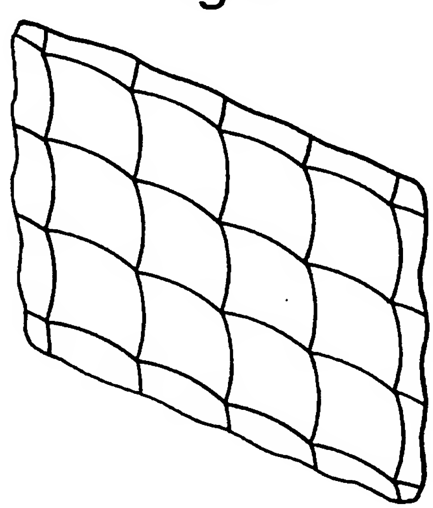

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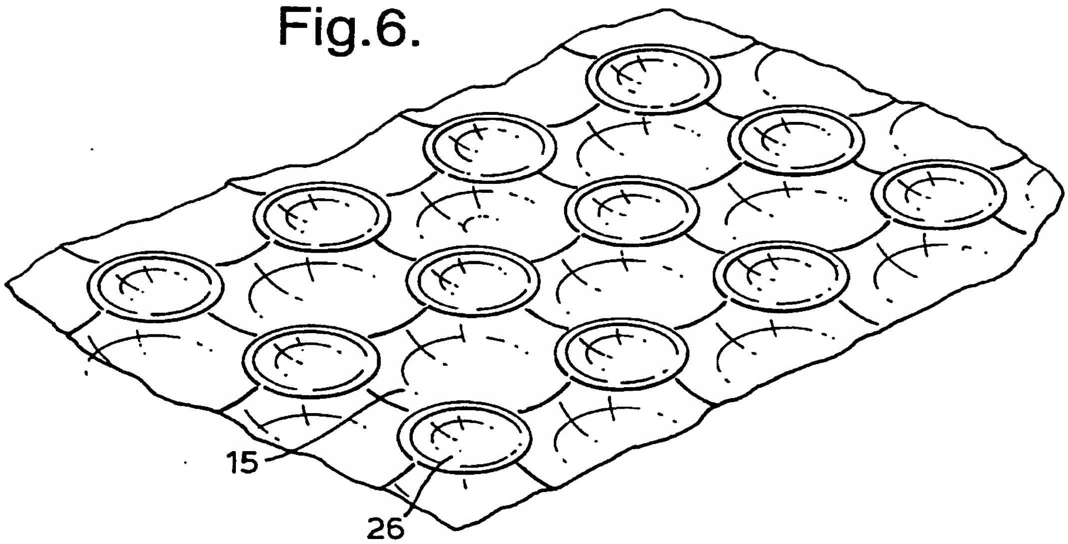

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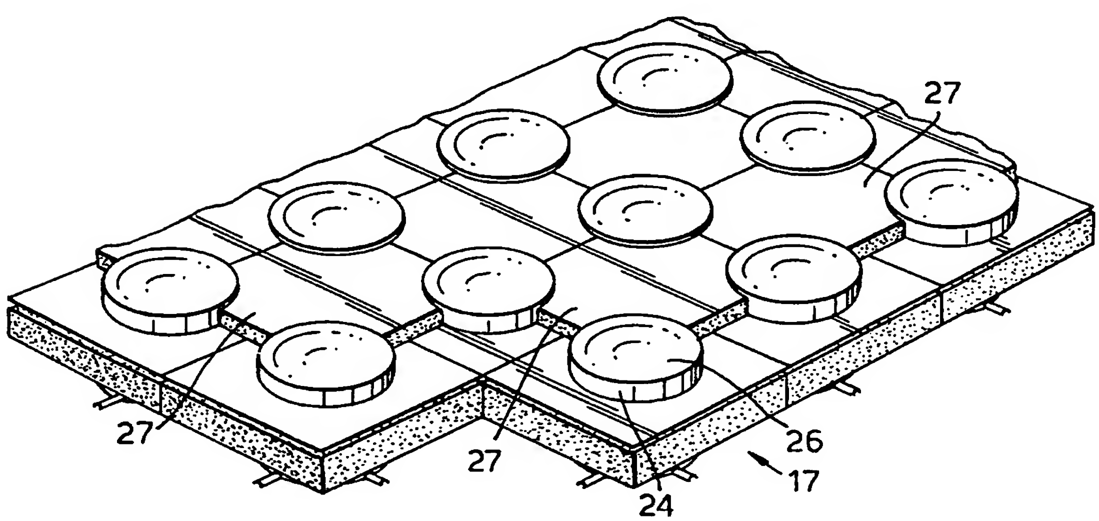

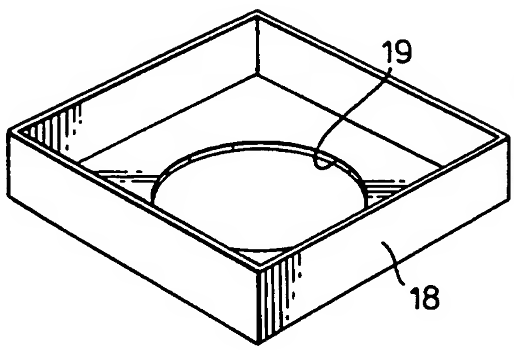

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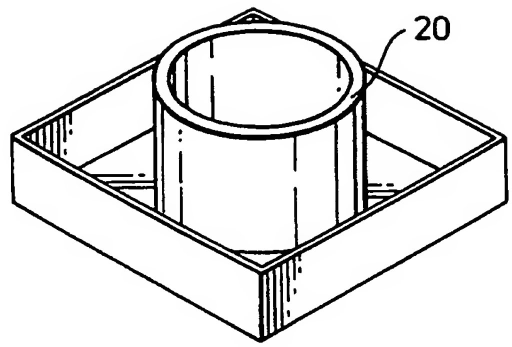


Fig.9.

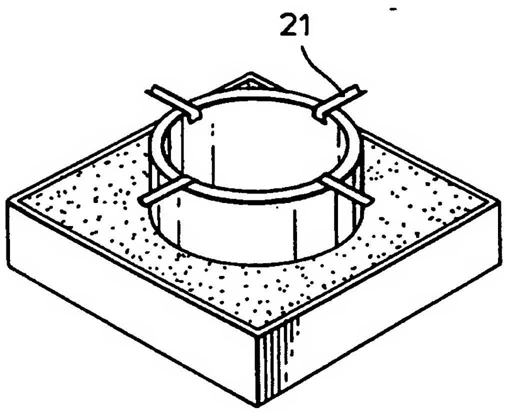
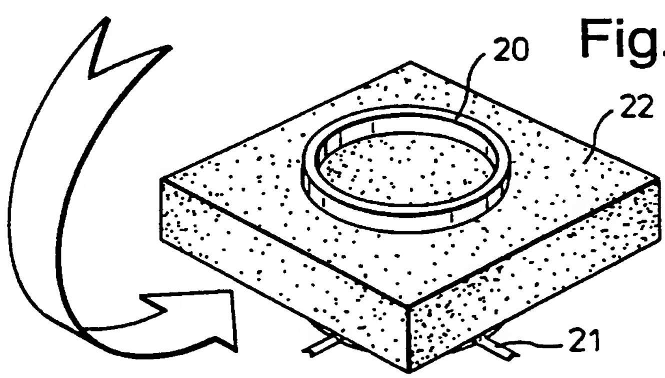


Fig.10.

Fig.11.



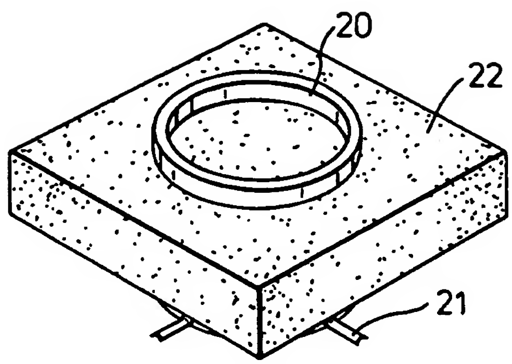


Fig.12.

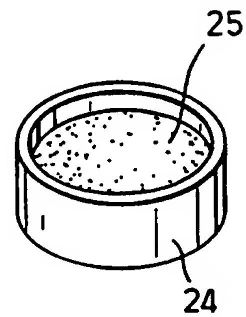
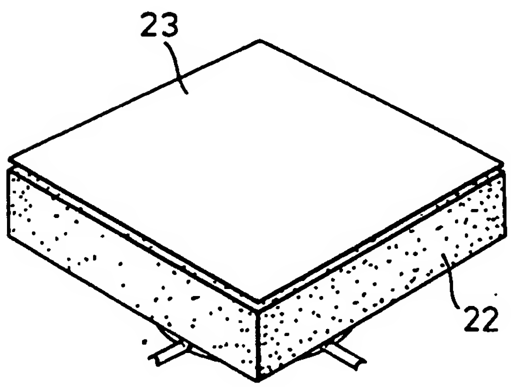


Fig.14.



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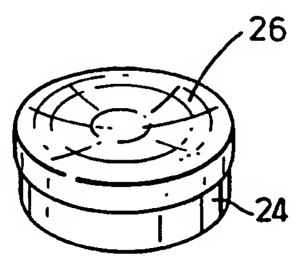


Fig.15.

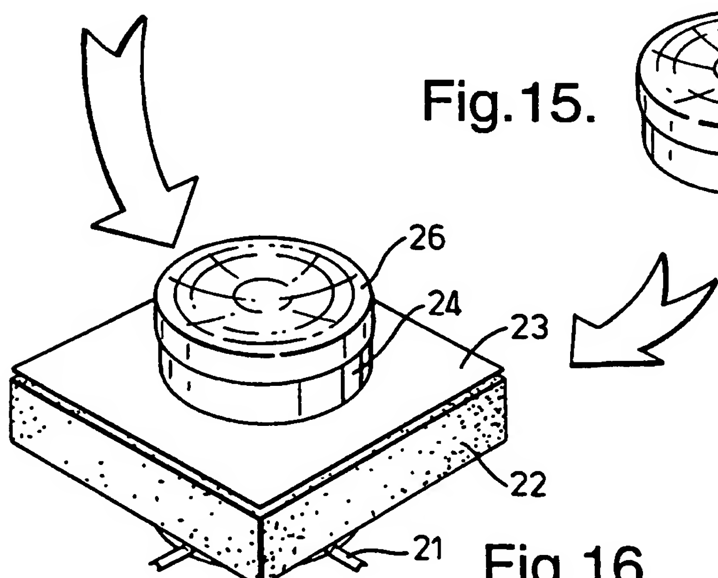
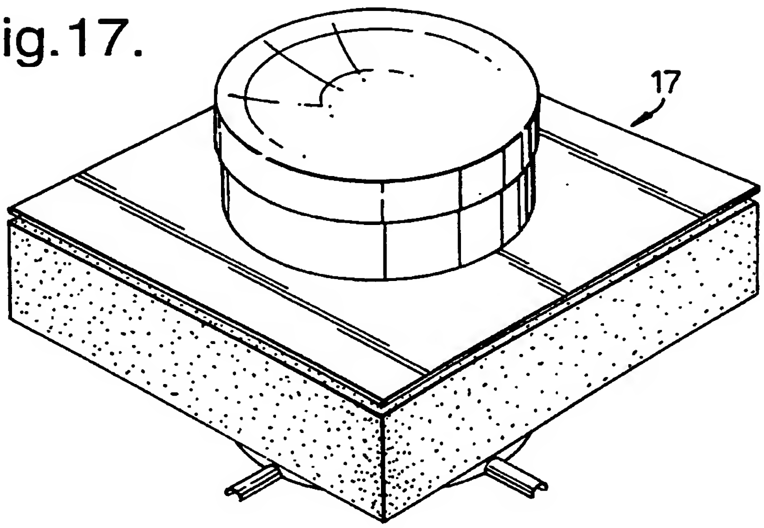


Fig.16.

Fig.17.



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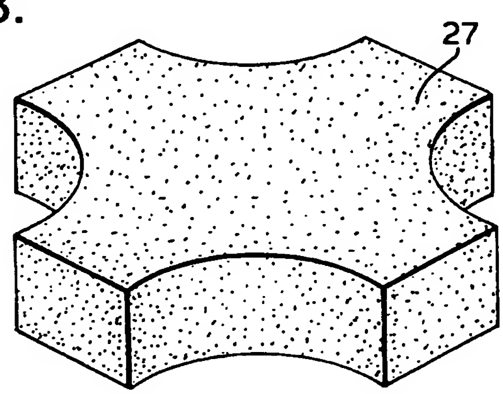

Fig.19.

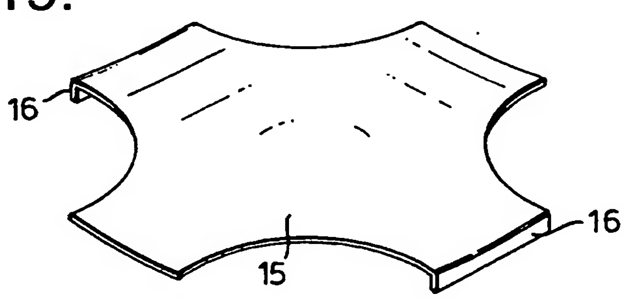

Fig.20.

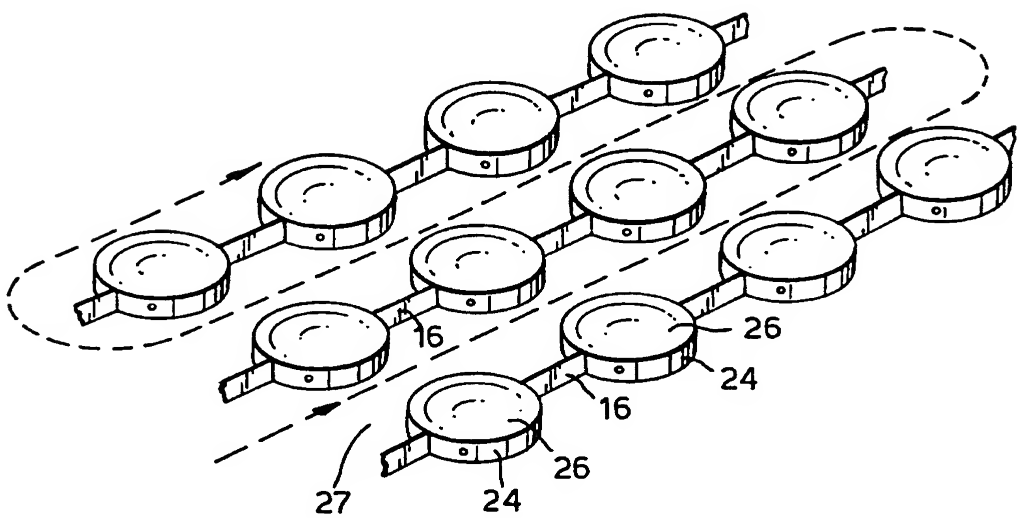
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Fig.22.

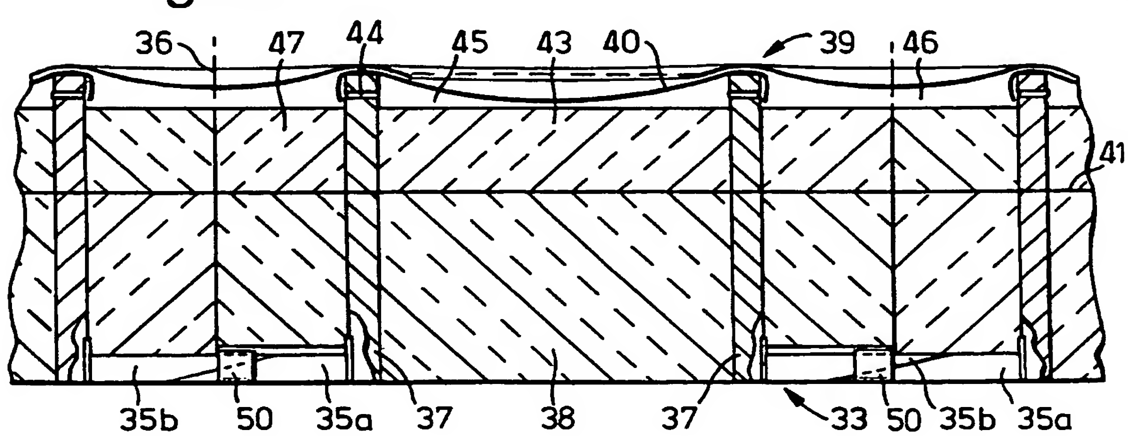
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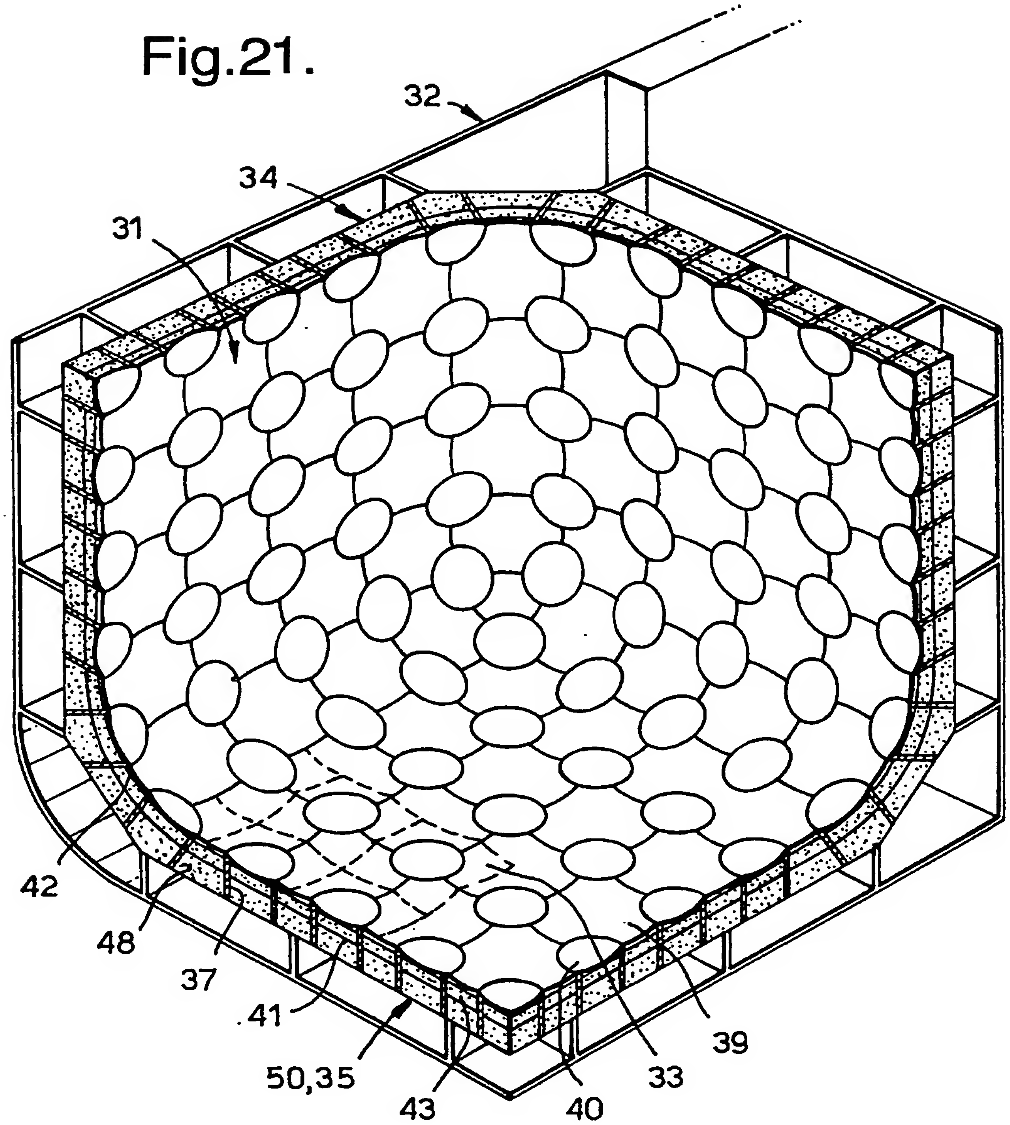
Fig.21.



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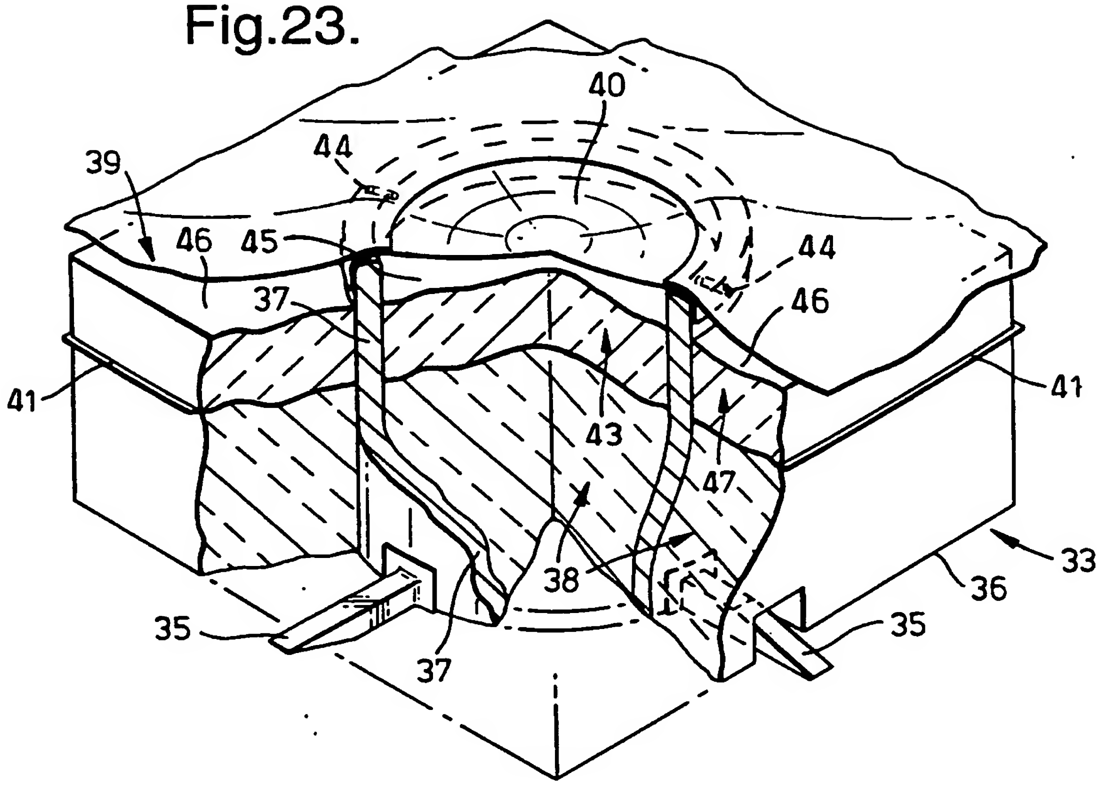
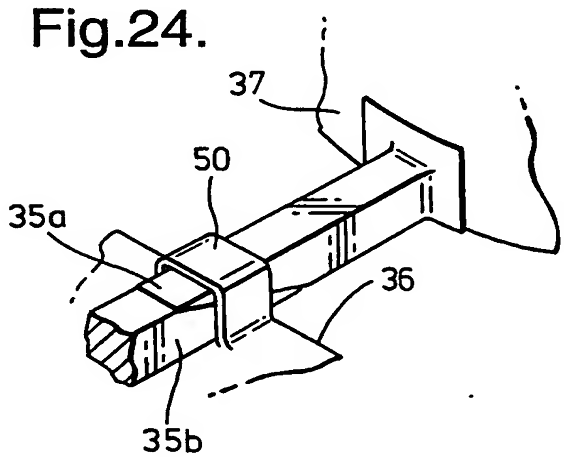


Fig.24.



INTERNATIONAL SEARCH REPORT

International application No.
PCT/NO 95/00051

A. CLASSIFICATION OF SUBJECT MATTER

IPC6: F17C 3/02, B63B 25/16
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC6: F17C, B63B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

WPI, CLAIMS, EPODOC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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X	DE 2708097 A1 (ASTILLEROS Y TALLERES DEL NOROESTE S.A.), 6 April 1978 (06.04.78), page 13, line 12 - line 16; page 17, line 3 - line 19, figures 4-6, claims 1-13 --	1-19
A	GB 1300730 A (CONCH INTERNATIONAL METHANE LIMITED), 20 December 1972 (20.12.72), claim 1 --	1-19
A	DE 2016442 A1 (CHICAGO BRIDGE & IRON COMPANY), 3 December 1970 (03.12.70), figure 1, details 14-17 --	1-19

[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

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- "O" document referring to an oral disclosure, use, exhibition or other means
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- "&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
6 July 1995	10 -07- 1995
Name and mailing address of the ISA/ Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Authorized officer Mårten Hulthén Telephone No. +46 8 782 25 00

INTERNATIONAL SEARCH REPORT

International application No.
PCT/NO 95/00051

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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A	FR 2068995 A5 (BRIDGESTONE LIQUEFIED GAS COMPANY LIMITED), 3 Sept 1971 (03.09.71), figures 1-2 --	1-19
A	GB 1442399 A (MARINE AND INDUSTRIAL DEVELOPMENTS LIMITED), 14 July 1976 (14.07.76), figures 7,8 -- --------	1-19

INTERNATIONAL SEARCH REPORT

Information on patent family members

29/05/95

International application No.

PCT/NO 95/00051

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